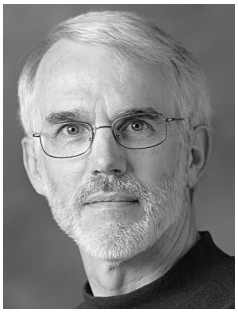
Scott McCoy, Associate Editor

The Role of the First Formant in Training the Male Singing Voice

Kenneth W. Bozeman



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FOR MUCH OF THE LAST CENTURY vocal registration was thought to be entirely a matter of laryngeal muscular adjustment, from a chest register (thyroarytenoid, TA) dominance in the lower range, through various degrees of chest (TA) and head (cricothyroid, CT) muscle coordination in the middle, to a head register dominance for the upper voice. For example:

> The term register refers to a portion of the frequency range, within the human voice, that is of similar quality and is so due to similar vocal fold activity throughout that range. In addition, there is little dispute that registers are physiologically created by the operation of the larynx. Generally, they result from variations in the thickness, length and mass of the vocal folds.[1]

While these laryngeal muscular adjustments *do* occur and are crucial to mastery of male *passaggio*, it is now clear that acoustic factors play a prominent, interdependent, and influential role. Timbral shifts previously thought to indicate changes in laryngeal muscular adjustment turn out more often to be caused by the changing interactions between voice source harmonics and vocal tract resonances (formants).

FIRST FORMANT AND SECOND FORMANT ROLES

The shift in prominence from the first formant (F1) to the second (F2) or, with some tenors, to the singer's formant cluster (FS) upon traversing the *passaggio,* has been well documented by Donald Miller,[2] and appears to be the preferred strategy of premier professional tenors. Miller and this author have independently pointed out the fact that a significant timbral shift occurs when the second harmonic (H2) of the voice source passes through the first formant (F1) of the vocal tract, creating a sound variously described as "turning over," "tipping," or "covering."[3] If such shifts occurred primarily as the result of changes in laryngeal muscular adjustment (as previously thought), one would expect to encounter them at or near the same pitch for all vowels of a particular singer. Instead they occur somewhat independently of laryngeal adjustment and approximately one octave below the various first formant locations of each vowel, the moment at which H2 would be passing through F1 (Figure 1).

Though these timbral shifts are independent of laryngeal register, allowing them to occur in their proper locations does facilitate more efficient laryngeal adjustment. Awareness and understanding of where and why these shifts occur, vowel by vowel, becomes very useful in devising strategies and exer-

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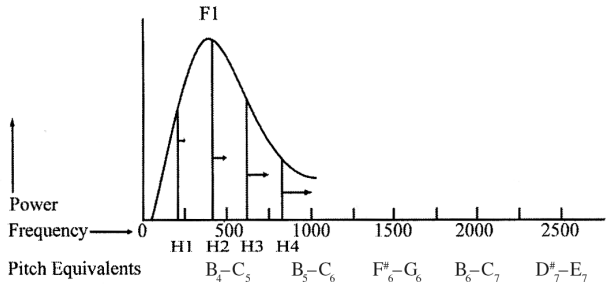


Figure 1. Second harmonic sweeping past first formant.

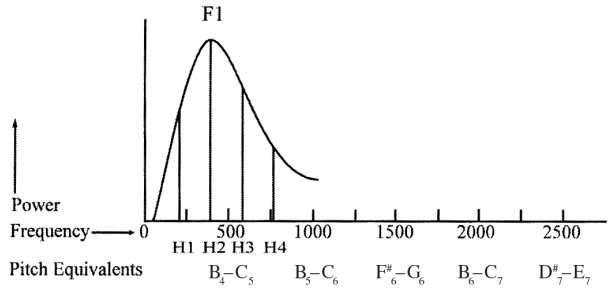


Figure 2. F1/H2 "yell" coupling.

cises to encourage successful range negotiation. As mentioned above, while the search for beneficial F2 (or FS) couplings with higher harmonics is clearly necessary for a finished, professionally viable upper register, appropriate stabilization of the vocal tract length and negotiation of the *passaggio* through attention to this first formant phenomenon is, in this author's experience, a prior and necessary foundation. This article will explain and explore the use of the first formant phenomenon in laying that foundation. It may be both possible and desirable to attend to both formant phenomena simultaneously.

THE YELL AND THE WHOOP

Male voices tend to approach higher tones and loudness levels from one of two instinctive behaviors: the yell or the whoop (or hoot).[4] The former is instinctive for survival and the latter for celebration. They are produced with rather different laryngeal adjustments and by means of different acoustic strategies. The yell is strongly chest register dominant and is characterized by an F1/H2coupling (Figure 2).

A sound in which two or more harmonics are at or below F1 is open in timbre. Such a sound is entirely appropriate for pitches more than an octave below the normal F1 of the vowel being sung. However, once the second harmonic approaches the peak frequency of the first formant, a strong acoustic F1/H2 coupling occurs, which, if carried above that pitch, soon becomes a yell with increasingly pressed phonation. In order to continue this F1/H2 coupling with rising pitch (and thus postpone turning the vowel over), the singer raises F1 to stay approximately an octave above the sung pitch. This is typically done in two ways: 1) by opening the vowel more; and/or 2) by shortening the vocal tract through raising the larynx. The former strategy can be reasonably well done over a small interval, *if* a more open vowel is available. For example, in English [eI] can be opened to [ɛI], and [oU] to [ʌU] (with [ɑ] there is no such option, since it is the most open vowel with the highest F1). However, such a change only works for about a major second, compromises diction to some degree, and is not acceptable in languages with purer vowel expectations. The latter strategy (raising the larynx) is accomplished by the activation of swallowing muscles, which not only shorten the vocal tract (hereafter referred to as the tube), but also constrict the laryngopharynx. This maneuver makes the vocal timbre shallower and increasingly interferes with the freedom and ability of the larynx to shift to a headier laryngeal adjustment. The resultant phonation becomes increasingly pressed and loud, hence the designation, "yell." In situations where *survival* is the objective, the subject is neither concerned with effort, pressure levels, nor sustainability; rather, with power and projection (and getting help!). However, for beautiful, flexible, sustainable singing, this is not a promising strategy. Characteristics of yelling include:

- more open, tongue-fronted vowels such as [ɛ] (help) and open articulation of [eI] (hey, yay), or [ɑ] (Mom!), since these vowels have an inherently higher F1 which will couple more easily with a higher H2;
- association with more stressful emotions such as fear, anger, or aggressive celebration;
- higher breath pressure and glottal resistance levels (pressed phonation, more blatant or strident timbre);
- pharyngeal constriction, laryngeal elevation, activation of swallowing muscles;
- a lower healthy upper pitch limit than whooping.

The whoop is essentially a reinforced falsetto, with a strong F1/H1 coupling (Figure 3). This occurs more naturally with close and/or lip rounded vowels, which

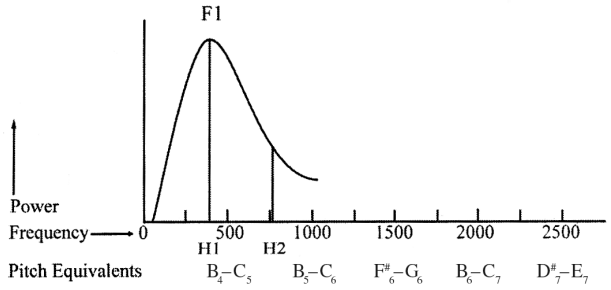


Figure 3. F1/H1 "whoop" or "hoot" coupling.

have inherently lower first formants, such as [u] (woo!) or in the case of yodeling, [i] (yodel-ee-ay-*ee*-hoo). Higher pitches can be achieved with significant power yet lower pressure levels than would be possible with yelling. Whooping is more often associated with joyous exuberance and celebratory exclamations. However, being essentially falsetto, it must be relatively high and weakens upon descending. Alternation between these two modes (yell and whoop) is typical of yodeling. Characteristics of whooping include:

- close, lip rounded vowels with a low F1 [u] (woo-woo!);
- falsetto laryngeal adjustment;
- high pitch (near the top of or above the *passaggio*);
- lower pressure levels than yelling;
- hootier timbre;
- yawnier, opened or settled pharyngeal space;
- joyful, celebratory emotions.

These two modes feel so disparate to the young male singer that for most no middle ground seems possible between them.

STABILIZING TUBE LENGTH

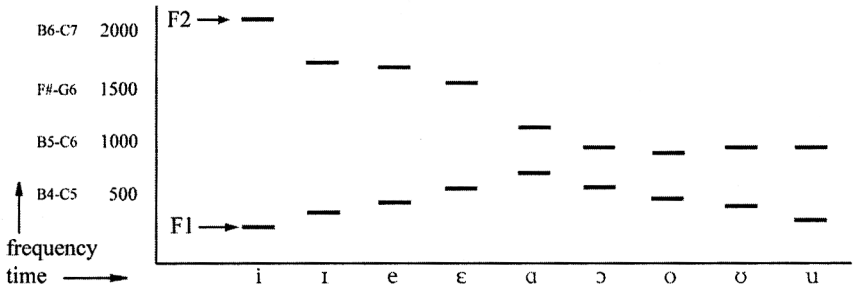
Male *passaggio* training requires a stabilized, "floated" laryngeal position and some degree of pharyngeal space (no swallowing muscle activation). The challenge for the singer is to continue to use a laryngeal mixture of head and chest muscle activation while maintaining tube length. This will necessarily result in H2 passing through and above F1, yielding its power position to a higher harmonic/formant coupling, which varies by vowel and circumstance, and eventually for some vowels to an H1/F1 coupling. This results in the previously mentioned timbral shift that is variously termed turning over, tipping, vowel modification, or covering (though covering is associated by some with pro-actively *lowering* the larynx, widening the pharynx and rounding the lips, precipitating the acoustic shift by lowering the first formant). An appropriate timbral shift is possible, in fact inevitable, with rising pitch when there is *no shape change in the tube*, as can be demonstrated with a voice synthesizer. In such cases, the shift results from the changing relationships between rising source harmonics and stable tube formants.

PASSIVE VOWEL MODIFICATION

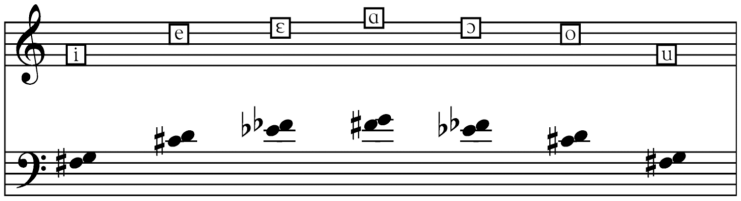
Keeping the tube shape the same while singing an ascending scale or glissando automatically causes timbral shifts and some degree of passive vowel modification as voice source harmonics pass through vocal tract formants. Vowels are identified acoustically by the perceived locations of formants one and two. However, because the tube can resonate and radiate only harmonic frequencies that have been introduced from the glottis, the actual locations of the formants (tube resonance peaks) are only approximately revealed to the listener. Our perception of formant locations will tend to center around the strongest harmonics being radiated from the lips, whether or not they are at actual vocal tract formant frequency centers. When H2 passes through F1 and begins to weaken, H1 will increase in power as it approaches the first formant peak, becoming the dominant low frequency and temporarily creating a somewhat lower perceptual F1. Close vowels have lower first formants. Therefore open vowels will seem to have shifted somewhat toward a closer vowel upon turning (for example: [ɑ]—[U] or [Λ]).[5] This inherent *passive* modification can be moderated if necessary to maintain vowel integrity by making some adjustments of tube shape, preferably not, however, by raising the larynx.

FIRST FORMANT LOCATIONS AND IMPLICATIONS

Compare the spectrogram of vowel formants below to the musical stave of first formants with the pitch of turning an octave lower (Figure 4). Several things are apparent that have pedagogic implications. First, there is the obvious parallel correlation between first formant locations and registration phenomena. Second, first formant locations are directly related to vowel openness/



Spectrographic model of the vowel formants of various vowels



Lyric tenor *passaggio* events
(locations of transitions relative to 1st formants)*

Figure 4. Spectographic/stave comparison of first formant locations.

* Vowel boxes are placed at their approximate first formant locations; pitch clusters indicate the pitches at which those vowels will close or "turn over."

closeness: the more open the vowel, the higher the first formant, and therefore the higher the timbral shift. It is useful to note vowels from "both sides of the (front/back) street" that share first formant locations: [i] and [u], [e] and [o], [ɛ] and [ɔ], etc. These can be paired and alternated in vocalises. Notice that [i] and [u] share the lowest first formant, whose location is so low—well below what one would consider to be the *passaggio*—that the closing/turning of these vowels often goes unnoticed. However, experiencing this acoustic shift independently of major laryngeal muscular shifts is kinesthetically and aurally instructive for the singer. Furthermore, with [i] and [u] the male singer faces in his upper voice the situation female singers deal with eventually with all vowels: the need to open vowels when the sung pitch (H1) exceeds the spoken F1 location in order to track an F1/H1 coupling.

Close [e] and [o] turn over at about the traditional location of the *primo passaggio,* that is, near the beginning of the *zona di passaggio* or transition zone. [ɛ] and [ɔ] turn over in the middle of that zone, and [ɑ] turns over near the *secondo passaggio,* or the entry into the true upper voice. *Nota bene:* these locations assume a stable tube length/laryngeal location. Changes in tube length or pronunciation will move the first formant locations and therefore the locations of turning. Other vowels' turning locations can be surmised from their relative openness/closeness. Being aware of these differing locations and exploiting them has benefits for smoothing register transitions for all vowels and for coaxing more reluctant vowels through these transitions.

SUGGESTED EXPLORATIONS

A useful training exploration is to "speak" a vowel using good stage resonance with a looping inflection that deliberately crosses over the pitch where that vowel would be expected to turn over. Below that pitch the vowel may seem to be speech-like, open, and clear, and to ring directly out of the mouth. As the vowel slides above the pitch of turning, the voice should flip or turn over, and the resonance may seem somewhat domed and more

highly "placed" in the head. The inflective loop may need to cover about a perfect fifth (from a third below to a third above the indicated pitch of turning) for one to fully experience the shift, since a vowel's transition is gradual and spreads over an interval of about a major second to a major third. This is easiest with [i] and [u]. If an open-timbered [i] does *not* turn over or close upon sliding through this area, it will tend to open to [I] and lose integrity as an [i]. Likewise, an [u] that doesn't turn over will open toward [U]. Once a vowel *has* appropriately closed or turned over, it will *need* to be opened somewhat, starting from about a minor third above its point of turning. To retain or maximize power and brilliance, a higher formant/harmonic coupling will also need to be found after a vowel has turned over.

Knowing the perceived vowel modification that occurs passively when the tube shape is retained but the pitch is raised forms the basis for more pro-active modifications, if needed, or at least for giving the sound "permission" to modulate/migrate appropriately. For example, in the above exploration, an [o] should migrate toward [U] or [u] upon ascending, rather than opening toward [ʌ]. This author recommends working to retain the timbral depth (laryngeal height) and the lip shape of the intended vowel while allowing the vowel quality to migrate passively until the vowel has turned over. The singer may also perceive himself to be opening more internally. The eventual goal is to allow appropriate, subtle timbral modulations while preserving a sense of vowel integrity/purity.

PERCEPTUAL CHARACTERISTICS

All vowels at the point of their turning move from open timbre *slightly* toward "whoop" timbre. This shift might cause the tone to feel and sound as if it is farther back, since H1 is approaching F1, which is a "hootier" resonance, perceived more pharyngeally. This must to some extent initially be allowed to happen to facilitate a stable, floating larynx, but can be moderated by encouraging a higher frontal orientation (behind the nose/cheekbones/eyes). As higher (F2 or FS) couplings are found to complement this F1 phenomenon, a *chiaroscuro voce chiusa* timbral balance can be restored.

The key issue here is that by allowing vowels to turn at their appropriate locations, activation of swallowing muscles is discouraged, an appropriately open throat (floating larynx) is encouraged, and the resultant absence of laryngeal constriction facilitates vocal fold adjustments toward lighter registration. Conversely, instinctive avoidance of tipping in an effort to keep the vowel speech-like or "forward" (both worthy objectives) usually invokes the larynx raising yell response, which in the end does not preserve a good vowel anyway.

Exercise Principles

Exercises can be fashioned that take advantage of the first formant phenomenon by:

1) attempting to stabilize the tube shape during ascent until the vowel has turned over *before* externally opening the vowel;
2) using choice of vowel, vowel substitution, or anticipation of passive vowel modification to encourage the larynx to float low and the voice to turn over at the appropriate locations for each vowel.

Exercise Progression

A useful exercise progression, from easiest to most challenging is:

1) Exercises that leap from a low open vowel [ɑ] to a high close vowel [u]. (This facilitates the kinesthetic experience of the timbral shift.)
2) Exercises that leap above a point of turning and back on the same vowel, attempting initially to maintain tube shape (imitating the spoken inflective loop mentioned above, but with specific pitches, such as *do-sol-do*; this will facilitate exploring/discovering passive vowel modification).
3) Exercises that leap above a point of turning, and then descend with stepwise movement, gradually re-opening: *sol-do-ti-la-sol*. (It is usually easier to find gradual, step-wise timbral changes when descending.)
4) Exercises that descend stepwise, then reverse and ascend stepwise: *sol-do-ti-la-sol—sol la ti do sol*. (This is useful for immediate modeling and comparison, since the initial descent is likely to be more successful.)
5) Exercises that ascend stepwise. *Sol—la—ti—la—sol-fa-mi-re-do; do-re-mi-fa-sol-fa-mi-re-do.* (This is the most challenging, but very instructive; once the singer has experienced the quality and sensation of

a vowel turning over, it will be easier to allow the vowel gradually to migrate in that direction during step-wise ascent.)

COMPLEMENTARY STRATEGIES FOR IMPROVING LARYNGEAL REGISTRATION

Several complementary strategies have proven helpful in lightening the muscular adjustment of the larynx and can be attempted simultaneously with first formant strategies:

1) avoidance of a crescendo upon ascent (a crescendo often is accomplished through a pressure increase);
2) avoidance of a breath pressure increase upon ascent (by active attention to buoyant rib expansion and minimal chest compression);
3) the use of expression or affect to instinctively raise pitch without increasing volume, pressure or constriction (for example: sobby, pathetic, pleasant, surprise, good idea/epiphany, joy);
4) the slight deepening and closing of a vowel (encourages turning over), or avoidance of opening and "shallowing" (spreading) of the vowel;
5) manually monitoring the thyrohyoid space on either side (this space clamps shut and is elevated with swallowing; it should remain loose, open, and low-floating for phonation)[6];
6) imagining expressive inflective movement while sustaining a pitch (encourages flexibility in registration);
7) singing a glissando from open timbre low notes on open vowels up on a large interval, such as a octave, to a heady close vowel and back to the starting pitch: *do—do—do* [wɑ—u—ɑ]; [wɑ—U—ɑ]; [wɑ—o—ɑ]; (Allow the upper note to flip to an open throated falsetto as soon as needed for ease. Monitor the thyrohyoid space—no change is ideal. This exercise provides kinesthetic experience of the laryngeal register poles, and rehearses maintaining an open throat or floated larynx across that change.)
8) though there will be some increase in hootiness on the top tones because of the shift toward "whoop" mode, the overall tonal sensation should be aligned and centered with a forward (rather than backward) trajectory; as more robust vocal fold adjustments become possible, a better timbral balance (i.e., with more ring) will ensue;
9) surrounding a resistant vowel with a closer glide or vowel will encourage the more open vowel to transition successfully: [jɑI], [wɑU], [jɛI].

CONCLUSIONS

In training the young male singer to freely and resonantly negotiate range:

1) The vocal tract length must be stabilized, i.e., the larynx must consistently float low, and swallowing muscles must not engage.
2) If the tube length and shape is consistent, vowels will acoustically shift about an octave below their first formant locations. Knowledge of those locations can be used to help train and habituate a stable laryngeal position.
3) The *variety* of vowels' first formant locations, and thus their points of turning, is good for the voice, freedom inducing, and pedagogically useful.

NOTES

1. Harry Hollein, Oren Brown, and Rudolf Weiss, "Another View of Vocal Mechanics," *Journal of Singing* 56, no. 1 (September/October 1999): 17–18.
2. Donald Miller and James Doing, "Upper Extension in Light of Visual Feedback," *Journal of Singing* 54, no. 4 (March/April 1998): 3–7; Donald Gray Miller, *Resonance in Singing* (Princeton, NJ: Inside View Press, 2008), 61–62.
3. Miller, *Resonance*, 61; Kenneth W. Bozeman, "A Case for Voice Science in the Voice Studio," *Journal of Singing* 63, no. 3 (January/February 2007): 267–268; Kenneth W. Bozeman, "On the Voice: Registration Strategies for Training the Male Passaggio," *Choral Journal* 48, no. 112 (June/July 2008): 63–64.
4. Miller, *Resonance*, 50–54.
5. One finds the use of both *close* and *closed* in descriptions of vowels to designate the quality opposite to open. While there are problematic implications with either term, this author prefers to use *close*, which is descriptive of the articulation of the tongue relative to the palate (rather than closed), and which also enables the use of *closer* to indicate degrees of closeness. This usage is also consistent with the International Phonetic Association.
6. Locating the thyrohyoid space: find the sides of the hyoid bone, usually near the top of the neck on either side; slide just below that, feeling for a dent or space. Swallowing will raise and close that space, yawning will lower and stretch it.

Kenneth Bozeman, tenor, holds performance degrees from Baylor University and the University of Arizona. He subsequently studied at the State Conservatory of Music in Munich, Germany on a fellowship from Rotary International. He is chair of the voice department at the Lawrence University Conservatory of Music in Appleton, Wisconsin, where he teaches voice, voice science, and pedagogy. He has received both of Lawrence University's Teaching Awards (Young Teacher Award, 1980; Excellence in Teaching Award, 1996) and an endowed chair in 1999. His former students have participated as apprentices at Sante Fe, Tanglewood, Seattle Opera, Houston Grand Opera, Central City Opera, and Utah Opera, and have sung with Houston Grand Opera, Boston Lyric Opera, Opera Colorado, Wolf Trap Opera, Seattle Opera, Sante Fe Opera, and Deutsche Oper of Berlin.

Mr. Bozeman has a strong interest in the application of voice science to singing and received the 1994 *Van L. Lawrence Fellowship Award* from the Voice Foundation for "excellence in teaching and active interest in voice science and pedagogy." He has been a member of the Editorial Board of the *Journal of Singing* for a number of years, serving as chair since 2000.

Mr. Bozeman was an active performer of recitals and of oratorio, including singing the tenor roles in the *St. Matthew* and *St. John Passions*, the *Christmas Oratorio*, the *B Minor Mass*, the *Magnificat*, and various cantatas of Bach, Handel's *Messiah*, Haydn's *Creation*, Mendelssohn's *Elijah*, and Vaughn Williams's *Hodie*. He has performed with the Milwaukee Symphony, the Wisconsin Chamber Orchestra, the Green Lake Music Festival, the Purgatory Music Festival of Colorado, the Louisville Bach Society, the Historical Keyboard Society of Wisconsin, and on Wisconsin Public Radio's "Live from the Elvehjem."